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A STUDY OF STRIDE LENGTH AND STRIDE RATE CHANGES AFTER HIGH SPEED TREADMILL AND SPRINT TRAINING

BY

DONALD ALEXANDER IRWIN

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The undersigned certify that they have read, and recommend to The Faculty of Graduate Studies and Research, for acceptance a thesis entitled "A Study of Stride Length and Stride Rate Changes after High Speed Treadmill and Sprint Training," submitted by Donald Alexander Irwin in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

The purpose of the study was to investigate changes in stride length and stride rate after a training programme of high speed treadmill and sprint running.

Three groups were randomly created from a ranked list of one hundred metre performance times. Each subject was filmed while running the 100 metres before, midway and following a seven week, thirty training session programme. A 16 millimeter Bolex spring loaded movie camera with TRI-X Reversal Film was used to film each run. Filming took place from an elevated press box ninety yards away from the subjects running on an all-weather grasstex track. The camera was panned to follow the runners throughout the 100 metre distance and stride rate and length were calculated from the film.

A multiple analysis of variance was computed on both stride length and rate scores. Significant F scores were found in two cases. Firstly, the stride length changed significantly in all groups and in all testing periods as the runner progressed through the 100 metre distance. Secondly, there were significant differences in stride rate in all runs between various segments of the race.

There were no significant differences between training groups or testing times on either stride length or rate.

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CHAPTER 1

STATEMENT OF THE PROBLEM

INTRODUCTION

Running at top speed is common to almost every sport but research into methods or techniques of improving running speed have been very few in number.

For many years, and still in some circles, running speed has been considered innate and unchangeable. Now the trend is changing with coaches realizing that training can improve one's speed. Recently, training methods using towing (Sandwick, Archey) and a high speed treadmill (Dintiman, 1971B) have produced remarkable sprint improvements. These findings have rekindled interest into researching new training methods, and investigating changes resulting from these methods.

The systematic analysis of the components of sprinting has not been possible without the advent of high speed cameras and film. Now the run can be broken down into its various segments (stride length and rate) and how they change throughout the run. Frame to frame analysis can show changes in position and can document these on a time basis. The running action of a "faster" athlete can be compared to a "slower" athlete and information about the differences can be observed.

Force sensitive platforms enable us to analyze the forces exerted at various times in a stride cycle (Tsujino). Most research at present is concerned with the forces involved in the sprint start

but useful information may be collected from similar analysis of the remaining 95% of the race.

The Problem

In this study the changes in stride length and rate was compared for two training groups and a control group. Training methods included pace training on a high speed treadmill and unaided sprint running.

The null hypotheses for the problem were:

1. There will be no changes between groups after training in either stride length or stride rate scores compared to the control group.
2. There will be no difference between the three groups scores in pre, mid or post condition in stride rate or length.
3. There will be no difference between the three groups in various segments of the run in stride rate or length.

Limitations of the Study

(1) All runs could not be filmed for each subject. The fastest (least number of frames) of those filmed has been analyzed for stride rate and length.

(2) With a spring loaded camera, film speed is slightly variable.

(3) The film speed was increased shortly after the start of the study in order to increase image clarity. A conversion factor of 41/30 or 1.37 was used to convert all results to the higher speed.

(4) It was not possible to control the activities of the subjects outside the training and testing periods.

Delimitations

(1) Twenty-one male volunteers of local track and field clubs and the University of Alberta were used for the study.

(2) All subjects were required to have a minimum oxygen uptake of 45 millitres per kilogram of body weight.

Definitions

Stride Length

The horizontal distance measured on the ground from the toe of one foot contact to the toe of the next foot contact.

Stride Rate

The number of frames from first frame of foot contact to the frame immediately preceding the next foot contact.

Increased Stride Rate

The number of frames between two foot contacts is less than the number between the preceding two contacts.

<u>Stride:</u> A stride is measured from one foot contacting the running surface to the opposite foot contacting the running surface.

CHAPTER 2

REVIEW OF LITERATURE

INTRODUCTION

The goal of all sprinting is to decrease the time it takes to run from point A to point B. By looking at the body mechanics involved in sprinting we are able to gain insight into how this time can be decreased.

Stride length and stride rate are two of the factors that can be used to analyze a sprint. An increase in stride length without a comparable decrease in rate can lead to a faster performance. James G. Hay points out that stride length is the sum of three components:

(a) the horizontal distance of the centre of gravity is forward of the toe of the takeoff foot at the instant the takeoff foot leaves the ground.

(b) the horizontal distance the centre of gravity travels while in the air.

(c) the horizontal distance the toe of the leading leg is forward of the centre of gravity on landing.

The length or distance of each of these three components depends on certain physical characteristics of the individual sprinter:

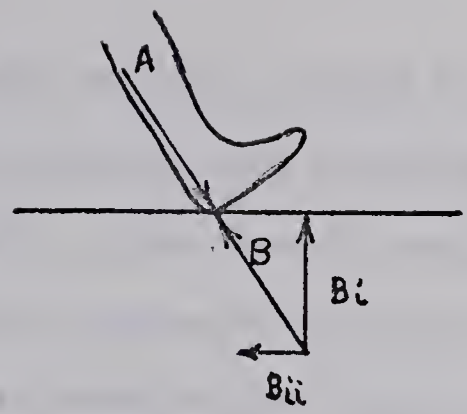
(a) this distance depends on the sprinters physical characteristics (length of legs) and flexibility (range of movement of hips). The extent the runner extends his leg before the foot leaves the ground and the angle the driving leg makes to the horizontal are other factors affecting this distance.

The angle of the sprinter's body to the horizontal varies from 30° as he leaves the blocks to 60° - 90° in full stride. Hence the centre of gravity is closer to the takeoff foot as the sprinter's velocity increases due to the increasing angle. This causes a decrease in this factor from the start of the race until full speed is reached.

(b) The distance the centre of gravity travels while in the air is governed by actions while the foot is in contact with the ground. Such factors as speed and angle of takeoff are determined at takeoff and are the limits in this distance.

The most important factor is speed of release which is primarily determined by ground reaction to muscular forces exerted by the athlete. These forces result from extension of hip, knee and ankle against the ground and hence the strength and speed of these muscular contractions are major factors in determining this distance.

(c) This distance from the toe to centre of gravity is the smallest contribution to the stride length. If the foot lands ahead of the centre of gravity, ground reaction forces result which slow the runner down. The runner, who swings his leg forward just before contact, increases the stride length but evokes a backward ground reaction force which slows the runner down.



A: Force Evoked by Overstriding
B: Ground Reaction Force
Bii Component of Ground Reaction force which slows runner down

FIGURE I
BODY AND GROUND REACTION FORCES ON FOOT CONTACT

This technique of overstriding is widely seen when sprinters are slowing down after a race.

STRIDE FREQUENCY OR RATE

Each stride can be subdivided into the time the runner is in contact with the ground and the time he spends in the air.

The ratio of these two components varies from 2:1 at the start to 1:1.3 - 1:1.5 at or near maximum speed for top class sprinters (10.0 - 10.5 for the 100 metres) (Housden).

(a) Time on Ground

This is governed primarily by the speed the muscles of the supporting leg can drive the body forward and then upward into the next airborne phase.

Slater Hammel has shown that the factor limiting stride rate is not the speed of the leg per se. The leg can stride at a rate of 5.6 to 7.1 cycles per second in bicycling. This value is far higher

than sprinting rate which has been recorded from 3.10 to 4.85 cycles per second. Therefore the sprinter could move his leg faster without the load of the leg and body. Slater Hammel concludes that leg rate is not limited by a neuromuscular mechanism but by the weight the muscles must move. Hence strength is cited as the limiting factor in rate of leg movement.

(b) Time in the Air

Again, as in stride length, this is determined by the velocity and height of the centre of gravity at takeoff.

RELATIONSHIP OF STRIDE RATE AND LENGTH TO RUNNING SPEED

The equation that stride rate times stride length produce the time for a sprint is often quoted but Hopper states that the quantities "are more closely related than this formal equation suggests" (Hopper, p. 1205). He points out that stride length and stride rate are dependent on the rate at which the grounded foot passes under the body in relation to the centre of gravity. Hence these two measures are determined by the running speed and not the reverse as indicated by the traditional equation.

RELATIONSHIP OF STRIDE RATE TO LENGTH AS SPEED INCREASES

Also studying the relation of stride length and stride rate Paul Hogberg found that at low speeds, increased velocity comes primarily from increased stride length. At a certain (high) velocity, (which differs from runner to runner), speed is increased mainly by an increase in stride frequency. The speeds he uses for measurement are 10, 20, 23, and 30 km/hr which are equivalent to 36, 18, 15.6 and

12 second 100 metre runs. He found maximum length of stride 210 - 218 cms. (84 - 87 inches) and a maximum distance between feet (in the air) of 150 - 155 cm. He concludes that leg drive, not leg length, has greatest importance in lengthening stride in fast running. Nelson and Osterhoudt show that stride length in runs of 11 to 16 ft/sec to 21 ft/sec (29.7 - 20.5- 15.6 100 m times) increases from 53 to 67 to 76 inches. Stride rate changes from 2.65 to 2.95 to 3.45 strides /sec as speed changes similarly. Both stride rate and length here reflect the same pattern as Hogberg reported. Sinning and Forsyth's research concurs with these findings as well.

Cavagna, Margaria and Arcelli used a high speed camera to study two international class Italian athletes (a sprinter and a 3000 metre runner) sprinting for 30 metres from the start. They found:

(a) stride length increased with the distance run (at 30 metres it was 2.2 metres).

(b) the length of stride seemed to be the linear function of the average speed of progression whether the runner was accelerating or running at a constant speed (up to a limit of about 6 metres per second).

(c) Step frequency of the middle distance runner was constant at 4 per second while the sprinter reached the much higher value of 5.5 steps per second during the first steps. The sprinters frequency was much higher in the acceleration phase than the sustained run. Cavagna cites this higher frequency as one of

the main factors responsible for forward acceleration given to the body by the sprinter.

(d) The sprinter's stride frequency declined from 6 per second to 4.5 at maximum speed. Cavagna et al states also that in a sustained run (not defined) the frequency increased with speed, tending to the same frequency limit 4.5 steps per second.

Some researchers view stride length as a function of body height or leg length. Wilt and Rampotti both agree that stride length at full speed can be calculated by multiplying height by 1.17. Rampotti further says stride length can vary by four inches on either side of 1.17 x Body Height.

Karol Hoffman uses 1.14 times body height or 2.11 times leg length to calculate average stride length. He cites the maximum stride length occuring between 50 - 60 metres in a 100 metre race. Maximum stride length can be calculated by adding 18 cm or seven inches to the average stride length.

A short sprint of 100 metres can be viewed as an acceleration phase, a phase of maximum speed, and a slowing down phase. The runner starts at zero velocity and increases velocity (accelerates) until he reaches top speed. He holds top speed for a short time and then slows down. He is not able to maintain top speed for more than 15 - 20 yards.

Hence a sprinter may improve his running time by

(a) accelerating faster to full speed (faster start)

(b) increasing his maximum speed

(c) holding his maximum speed longer

(d) slowing down less

A physiological analysis of the run provides more information into some of the observed changes in a 100m run. Dintiman (1971A) states that the 100m run is performed 95% anaerobically. He states that conventional sprint training has been only 25% anaerobic and 75% based on aerobic training. Sprint training should be changed to reflect its 95% anaerobic component.

A 100 yard dash requires about 11 litres of oxygen with only 2.7 litres available in the tissues and blood. Therefore the runner goes into an oxygen debt with anaerobic metabolism providing the energy.

The stores of energy rich Adenose triphosphate (ATP) are exhausted in about eight seconds (around the 65 - 70 yard mark). Around this point in the race the athlete is observed to slow down perhaps due to the depletion of this source of muscle fuel. Figure I shows the energy sources for physical exertion of various durations.

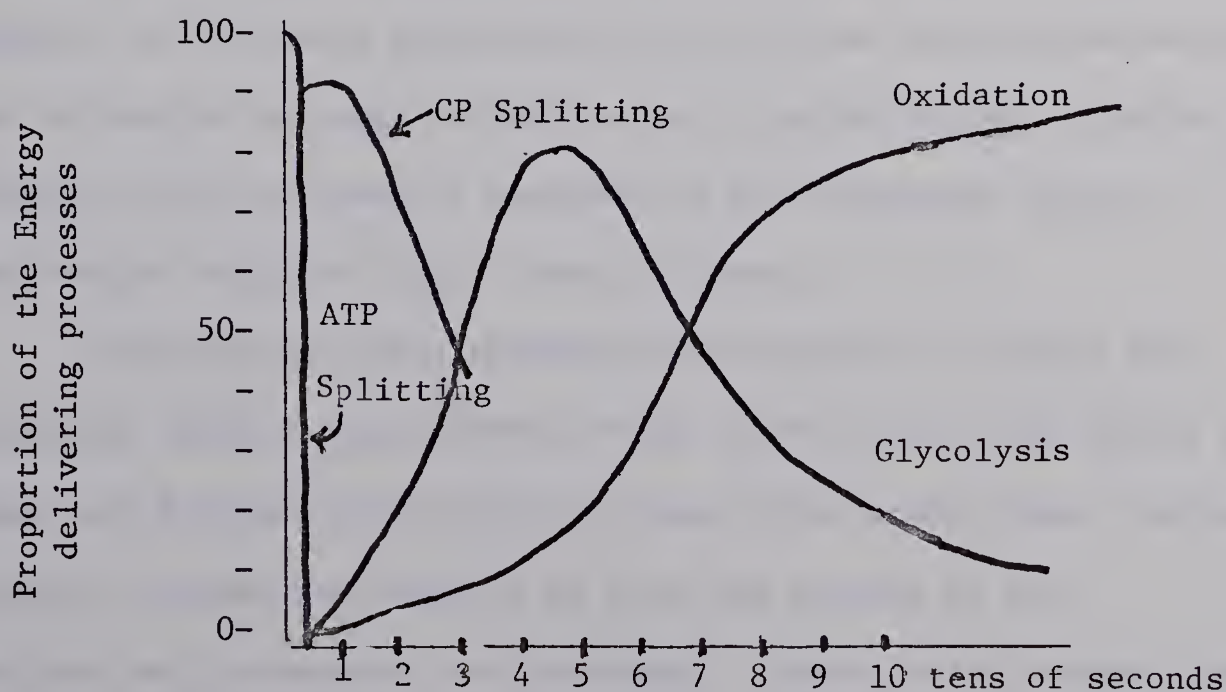


FIGURE II

ENERGY SUPPLIES FOR SPRINT RUNNING (from KUEL, DOLL & KEPPLER, page 50).

Once a sprinter goes into oxygen debt, the amount of debt depends on his training (speed with which the body can change lactic acid back into an energy source), his age, and nutrition (Kuelstal). Lactic acid, the product of anaerobic metabolism, is able to slow down contractions and, if the level is high enough, even cause contractions to cease. This also may be a reason a runner slows down in the later stages of a 100 metre distance.

Training is able to decrease or delay the slowing effect of lactic acid, increase the energy store in the muscles, and hence improve one's time for the 100 metres.

In order to train anaerobically a full recovery is needed so the fatigue products are removed before the next training exercise.

MUSCLE INNERVATION

Rathbone reports (in Dintimans paper (1971A)) that in muscle there are fast (white) muscle and a slow (red) muscle fibres. However, if the nerve innervation to the fibres is reversed surgically the red muscle twitches as fast as the original white. This may indicate that the speed of movement is more dependent on the innervation than the type of muscle tissue.

Many authors have studied the mechanics of running and sprinting (Bunn, Cavagna (1964), Fenn (1929, 1930, 1931) Henry, Housden, James and Brubaker, Nett, Scott, Slocum, Slocum and James, Trafton, Tricker, Tsujino,and Wendell) so that the actions of the body are well documented and explained. Deshon using cinematographic

analysis found significant correlation between sprint times and the following components: a forceful push of the rear leg, high knee lift, long stride and placing the foot directly under one's centre of gravity.

In 1939, Hubbard reported an increase in speed was caused by an increase in propulsive force which resulted in a lengthening of the runner's stride.

Marlow states stride length improvement is much more effective in increasing horizontal speed than stride rate changes. His training ideas emphasize training in three phases: firstly concentrating on increasing stride length by concentrating on driving, then increasing knee lift and finally concentrating on increasing leg speed.

STUDIES DONE TO IMPROVE RUNNING TIME

Many articles cite the success of Valery Borzov at the 1972 Olympics as evidence to disprove the old adage "Sprinters are born, not made". Borzov started his career with a relatively slow 13.0 seconds for the 100m when he was 14 years old. Four years later, after showing he possessed good sprinting speed, Soviet scientists selected him for intensive testing and training. After 6 years he won two gold medals at Munich in the 100m and 200m sprints with performances equal and close to world record times.

Allen Farmer reports that the Soviets reviewed films of great sprinters past and present to find the best possible sprint action. They noted the powerful thrust of the extensor muscles

and the absence of restrictive tension. Borzov's technique was corrected from these films and he was given specific exercises to develop key muscles for optimal strength and power as well as relaxation. He possessed a perfect strength balance (legs and upper body strength). The scientific results showed Borzov did not possess the best natural speed but he compensated for this by developing endurance with strength training (hill running), fast sprints with long recoveries, and endurance runs (repeat 800m intervals) and one half hour cross country runs.

Borzov's training includes all the aspects of sprint training methods to be found in the research. In 1963, before the advent of Borzov, Doherty and Marlow had been recommending this holistic training approach for sprinting.

TRAINING METHODS

(a) Training Involving Sprinting at Various Speeds and Distances.

Many of the following training methods succeeded as they isolated the condition factor from sprinting.

Glinski compared fartlek (continuous change of pace running - speed play), interval training (running an interval and then recovery by walking or jogging) and sprint training (sprint short distance, fuller recovery) and found each equally effective in improving time for a sixty yard run. Also in testing using an 880 yard run, significant improvements were recorded only for the fartlek and interval training groups, indicating that these two improved running endurance as well

as running speed. The sprint training hence was equally efficient for the short distance speed but did not improve running endurance. All three methods improved leg strength equally as measured by a leg dynamometer.

E. J. Bentley performed a similar study using continuous running involving training at various distances. One group ran 220 yards and recovered by jogging 220 yards and repeating this pattern. The second group performed the same pattern for 110 yard sections and a third group trained at 55 yard distances. All three groups improved 50 yard dash times more than a control group but there was no difference between training groups. They also measured speed of movement of the extensors of the hip and flexors of the leg and these did not improve significantly over the control group. No differences were noted between training groups.

S. Kaledin studied a group of fourteen to sixteen year old boys in a one year long training programme that varied recovery intervals. Two groups were used with the short recovery group having rests of 1 - 1½, 1½, 2, 2 minutes between running 30, 60, 80, 100, and 300 metre intervals. The long recovery group had rest intervals of 50% greater (1½ - 2¼, 2½, 3, 3) minutes. At the end of the year both groups had equal improvements over 30 metres but at 60 metres, the short recovery group showed more improvement (0.9 seconds to 0.6). At 300 metres the short recovery group had an advantage of three full seconds. Hence we see for boys this age, the shorter recovery period produced positive results in distances as short as 60 metres. This may show that the short recovery group's greater improvement

was due to holding the speed for a longer time, or slowing down less.

Penny compared resistance running (type not specified) alone and in combination with weight training - isometric (static) and isotonic (moving) leg exercises and repetitive sprinting (sprint training). He found resistance running (alone or supplemented) significantly increased speed, leg strength and leg power. All variables showed an upward trend over two, four and six weeks. No difference was found between the four training methods.

Tressel studied the effects of three resistive training methods correct-o-sizer (seven foot rubber hose), exogenie (rope pulled through a pulley at set tensions) and weight training (barbells and Douglas weight machine). He found the correct-o-sizer and exogenies (involving resistance to the running action) more effective than weight training alone in improving running speed as measured by a 35 yard dash.

Winningham in a doctoral study at Southern California found a decrease in 100 yard times after training with ankle weights. Dintiman (1971A) states we must investigate immediate and long range goals of weight training programmes. He states there is conflict in the short range findings but long range leads to strength improvement. There is not sufficient information about Winninghams study to determine if it is short or long range. It is possible the weights caused slower leg frequency during the training which carried over after the training. A positive effect on sprinting may have been found by combining sprinting with and sprinting without the weights at various times in the study.

(b) Training By Running On A Sloping Terrain

In the late years of the 1960's training by sprinting on inclines received much attention. Research has firmly established uphill and downhill running as an aid to sprinting performance. Viru et al set up an experiment to compare nine different types of training.

They compared long steady running, fartlek, long sprints, interval sprints, interval series, endurance intervals, pace intervals, uphill intervals, and a combination of long steady, fartlek, and interval training methods. The 94 inexperienced runners improved their 100 metre times most with pace and uphill training methods. These training methods involve sprinting at 80 - 90% speed with 1½ - 3 minute recovery on uphill run on 15^{o} slope. The fact that all groups improved markedly in 100m sprint shows that all training methods improve sprinting ability although not as effectively as these sprint related and leg strengthening training methods.

Sprint training on a flat surface was compared with uphill and downhill surfaces and a third method combining all three surfaces in a study by Milakov and Cox. They found by combining up and down hill running with flat running gave the best results. The group was able to gain strength from uphill training and increase stride length and stride rate from downhill training. The sprinting on flat ground at the same time combined these changes into their running style to produce results superior to the separate methods. The authors note that the downhill grade should be no more than 2.6^{o} and uphill no more than 3.4^{o} for maximum improvement.

Another Russian researcher, Osolin, reports that after training on a downhill slope of 2 - 3°, stride rate increased by 17% when the subject returned to running on the level ground. Yugoslavian National Coach, M. Milakov asserts downhill running increases stride frequency and stride length and it forces the runner to adjust to speeds faster than those attained on the flat surface. He cites incline running as increasing leg strength, knee lift, rhythm and speed endurance. The combining of uphill, downhill and flat surface running leads to a change in rhythm and all of the attributes are blended into the runner's style.

(c) Weight Training

To increase strength by weight training should improve one's running time as a stronger pushoff increases stride length and performance (Hogberg). An increased stride length without a decrease in stride rate would produce a faster time.

O'Connell has stated that once an athlete reaches a highly skilled level, rapid improvement only comes by increasing leg strength.

Dintiman (1971A) states that the importance of strength in developing sprinting speed is well established. He cites it as essential in acceleration, explosive power, stride length improvement and in maintaining maximum sprinting speed. He lists six principles to follow in weight training: stretching after a workout, strength training used in conjunction with sprint training, concentration on the muscles involved in running, allowing the muscles time to recover

and rebuild between workouts and (if speed is the goal), then exercises should be performed explosively and heavy resistance exercises should be done after training (to prevent injury).

Many researchers have attempted to show an increase in speed of movement with an increase in strength. Pearson and Rasch concluded that static strength and strength in action are two seperate factors with little correlation. Chui compared isometric, rapid and slow dynamic weight training exercises and found all methods increased speed significantly over the control group although there was no difference between training methods. Henry and Whitley and Clarke hold to the principle of specificity of neuromuscular coordination. They state that "the amount of potential strength that is exerted in a movement of maximum speed is determined by the neural function in the coordination in integration centres of the nervous system rather than the muscle" (Henry and Whitley, page 26). Hence, weight training increases are mainly due to improved nerve muscle coordination. In an article in the same journal, L. E. Smith found gains in both pretensed and free arm speed following a programme combining static and dynamic resistance exercises. Zorbas concurs with this finding. Whitley and Smith discovered that as the mass increased the correlation between strength and speed also increased (the arm was used in this study). Chui used eight body measures (including leg speed) and found increased speed with strength improvements. Klafs and Arnhein concur with Chui and Whitley and Smith stating that a gain in strength is concomitant with gains in speed and endurance.

(d) Weight Training Combined With Sprinting.

Researchers have shown that weight training combined with sprinting is superior to weight training alone (Dintiman (1964) and Sweeting) or sprint training alone (Kusinitz). Schultz compared weight training, direct practice or repetitive sprinting and combinations on a battery of activities. He found at the 5% level of confidence, in 60 Yard dash, that underdistance repetitive sprinting either alone or combined with weight training can be used for a time improvement in the short dash and that weight training alone should be avoided. Jesse says training must be specific to sprinting actions. Strength training increases the runner's ability to develop fast and explosive movements at maximum speed as in starts and accelerations. Helixon found that progressive heavy resistance exercises using near maximum weights produced no significant difference in 100m dash times of first year high school track. Jesse says that arms, shoulders and hip flexor should be trained with 3 - 10% of maximum and heavy extensors in the hip and legs with 10 - 40% of their maximum strength. Muscle balancing prevents injury, as do flexibility exercises. Charles found that explosive weight training improved running speed but this improvement was not significant when compared to handball and trampoline training.

(e) Pace Training.

The training of athletes by forcing the athlete to keep up with a set cadence is not new. Paavo Nurmi the great Finnish runner

is reported to have used this method. Types of pace training vary from moving one's legs to a musical beat, running alongside a faster runner, and being towed by an automobile to attempting to keep up to a high speed treadmill.

The first mention of specific pace training occured when Charles Sandwick reported the towing technique in 1967. Mark E. Shuttleworth is hailed as the inventor of the method. Sandwick reports Shuttleworth found the method effective in increasing stride length, rate, and sprinting speed. The Sandwick method was to have runners sprint behind a car holding onto a bar attached to the rear bumper. He found stride length increased by six inches when the group returned to unassisted running on the track and found this gain to be permanent. He presents no data of speed increase but the record of victories in local and state competition strongly hint that his sprinters did improve their sprinting ability. Dintiman (1971A) reports that Sandwick found a decrease in 100 yards times from 10.5 - 9.9 in a five week period.

Archey refined his technique recently by using tow ropes whereby the runners hold handles of a rope which passes through a pulley attached to the rear bumper of a car. This allows the athletes to use their arms similar to normal running action. Again no results or data are reported, he only states his runners showed marked improvements. His athletes used conventional workouts and weight training on alternate days. Training paces varied: 9.0 second 100 yards for the sprinters to 2 miles in 9 minutes for distance runners.

Sandwick states improvement results from the muscles and joints involved attaining a greater range of movement than possible without towing. Both Sandwick and Archey point to more efficient running with less exertion as factors in the improvement.

The only systematic research on treadmill pace training was a study referred to in one of Dintiman's speeches (Dintiman 1971B). In an eight week, 27 session study involving weight training and treadmill running, the experimental group improved 20 yard times significantly over a group using weight training and conventional sprint training (Note The 20 yards was after a running start).

Dintiman (1971A) states that adjusting treadbelt speed to gradually increase the individual's rate of leg movement per second beyond what he is capable, will lead to improvement in running on a flat surface. He points to research where increased leg movement forced by a motorized bicycle ergometer carried over to increased rate of leg movement without motor assistance. He sees the faster leg alteration on a treadmill due to elimination of wind resistance and the aid of the treadbelt. The runner does not have the work of pushing himself forward but concentrates on making his legs go faster to keep up with the treadmill.

(f) <u>Treadmill Running Compared To Overground Running (Sprinting)</u>.

Nelson et al found only slight differences for stride length and stride rate between running on each surface. Subjects tended to run on the treadmill with longer strides and at slower rathes at the highest velocity (15.6 sec. 100m) - not a sprinting

speed. The time of support was longer and time on non support shorter for treadmill running. They account for the increase saying the runners "stretched out" the lead leg and let the supporting foot move with the belt backward. Vertical velocity of the centre of gravity showed less variability and was consistently lower in treadmill running. Mean horizontal velocities were very similar under both conditions due to matching, however, there were marked differences in variability.

Overground running was characterized by the acceleration (driving) and deceleration (non support, contact of foot, and support phase). Treadmill running did not possess this variability which could show the lack of a driving phase and/or less deceleration on foot contact due to the moving belt.

Two modifications of running are observed. The forward foot strikes ground further ahead of centre of gravity than in overground running and is returned by the moving belt beneath the runner. In order to maintain the same speed on the treadmill as overground, if he spends more time on the belt the runner must complete the recovery phase more rapidly in order to place the foot further out in front of his centre of gravity. Hence this phase, leg movement, must be faster.

Increased vertical displacement indicates energy is being spent to lift the body more in overground running, which is an inefficient use of the runner's energy. Treadmill training may teach the runner to sprint using a more efficient style.

Dintiman (1971A) charts the following as aiding and hindering factors in treadmill sprinting as compared with overground sprinting:

AIDING

no wind resistance

no unfavourable environmental conditions

energy conservation - steady, unaltered pace, less knee lift, no acceleration.

less time on weight bearing foot (less time to drive off which is a disadvantage as less force is produced.

motorized belt forces faster pace

Form correction possible while subject is sprinting (gross form correction, e.g. arms)

stride length increased

challenging - pre knowledge of belt speed

HINDERING

limited push off from weight bearing foot

form alteration required that affects positive transfer to flat surface, unaided sprinting.

Dintiman cites no references to current research to verify these factors.

Dintiman reports that braking is greatest in the initial stages of treadmill running and tends to be eliminated as acclimitization occurs. He states at high speed (beyond one's maximum) and in early use of the treadmill, the braking effect almost reduces the treadmill speed to a sprinter's maximum speed, but with continued training this effect is overcome.

An excellent summation of the types of sprint training and their objectives and goals is found in the following chart from Dintiman's extensive study: "The Techniques and Methods of Developing Speed in Athletic Performance." (Dintiman, 1971A). The only factor he does not include is the aerobic factor to sprinting which although small (5%), can assist maintenance of the stride length and rate for a longer period and hence improve the sprinting time.

FIGURE III

MAXIMUM

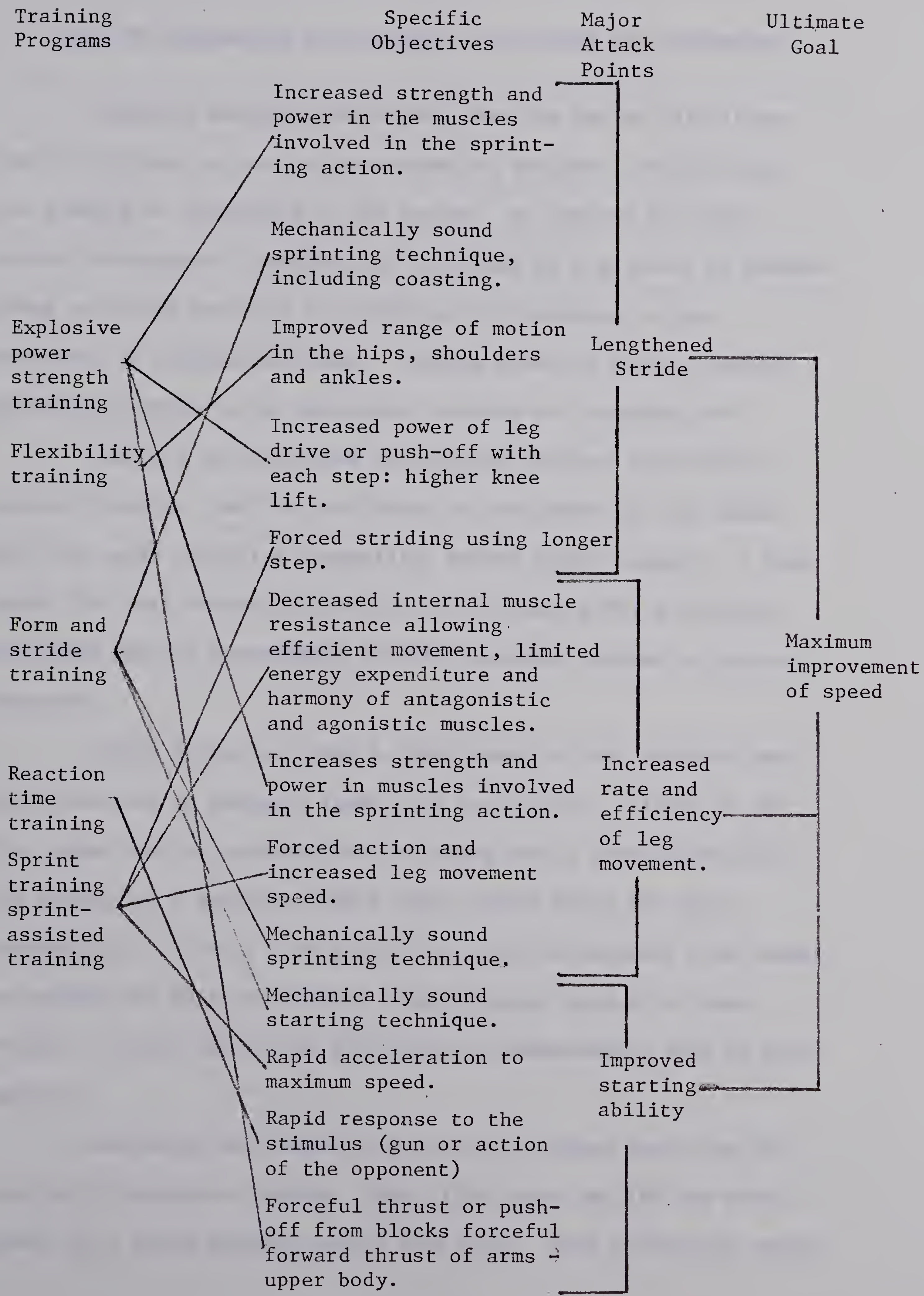


FIGURE III
MAXIMUM IMPROVEMENT OF SPRINTING SPEED THROUGH SPECIALIZED TRAINING PROGRAMS

USE OF PHOTOGRAPHY FOR ANALYSIS - EQUIPMENT AND PROCEDURES

Randolph Ketlinski points out that the use of film allows one to slow down action for more detailed analysis. This allows the viewing of components of the action. He reports the first case of photographic analysis was performed by a sequence of cameras being activated manually to determine if a racehorse's gait possessed an unsupported phase. Slowing down the action provides information which is an invaluable teaching and coaching aid.

Analysis by high speed photography involves controlling certain factors: time for the camera to accelerate to full speed and film speed variation (especially spring loaded camera). A high speed film with versatility such as 16 millimetre TRI-X Reversal Film (ASA 200) is recommended for film analysis studies in physical education.

Taylor points out that a 16mm camera is most commonly used as it provides an adequate frame size and clarity. Timing of the film speed can be performed with a timing device photographed with the subject or a built-in timing light, which marks the film automatically. Taylor also points out that the Recordak film reader to analyze the film has several disadvantages: lack of a frame counter, no lock in for the film, and all measurements must be done manually.

Osterhoudt and Nelson have done two studies involving film analysis of subjects running. Their film speed was 160 fps with a camera in a fixed position and at hip level. They calculated stride

length from the x-co-ordinates. Their camera (16mm) was equipped with an automatic timing device (film was marked every 1/100 second) which was used to determine stride rate.

These articles and advise from Technical Services at the University of Alberta were used to establish the most effective method of using filming to collect data on stride length and stride rate.

CHAPTER 3

METHODS AND PROCEDURES

SUBJECTS

Twenty-one male members of local track clubs,and students at the University of Alberta volunteered to take part in the study.

Anthropological data including major activities are listed in Table II.

Subjects were required to possess a fairly high level of fitness (an oxygen consumption of 45 millilitres per kilogram of body weight or greater) and be able to run the 100m in 14 seconds or less.

EXPERIMENTAL DESIGN

All subjects were pretested to determine their time to run the 100 metres. The total group was ranked from fastest to slowest on their best performance and was divided into three equal sections: fastest, next fastest and slowest.

A subject was randomly chosen from each group and this procedure was repeated until the first group was full. Then subjects were selected in the same manner to fill the other two groups.

The training groups and control group were filmed while running 100m before the training started (pretest), after three weeks of the study and at the conclusion of the study.

SUBJECTS PERSONAL DATA

Control Group	Age	Height	PreWeight	PostWeight	Major Activity
Ed Bennington	24	68	150	153½	Gymnastics, jogging for personal fitness.
Bob Marshall	22	73	167	167	Racket Ball.
Gord Osborne	19	69	165	162¼	Gymnastics, jogging for personal fitness.
Glen Bailey	29	66½	155	152	Personal fitness program, jogging and weight training.
Charlie Bonifacio					Gymnastics.
Bill McBlain	25	68	135	137½	Distance running.
Dave Yawrenko	21	67	148	149	Gymnastics.
Track Group					
Fred Gutoski	31	74	197	192	Decathlon
Ben Buss	29	75½	178	183	Cross Country Skiing & jogging
John Baxter	25	74	166	164	Distance Running
Lee Stelck	20	73	141	137	Hurdles
Bob Cote	20	72	133	135	Sprints
Larry Brinker	24	74	185	186½	Hurdles, and Contemporary Dance
George Stothart	33	72	196	189½	Sprints, Middle Distance, Basketball
Speed Treadmill					
Don Irwin	26	73	166	168 3/4	Sprints, Long Jump
Roger Burrows	25	71 3/4	147	144	Middle distance running
Barry Lange	22	71½	173	176	Decathlon
Richard Sherbaniuk	18	69	127½	128	Sprints
George Cuff	24	70½	150	149	Personal fitness, jogging & boxing
Tom Overend	19	70	139½	140	Speed Skating & jogging
Drew Lockhart	20	70	152	150	Long Jump
Ed Anderson	17	68½	152	157	Cycling & jogging

TABLE I

Each subject was required to run the 100 metres five times (with sufficient rest). The subjects were filmed on two occasions during each testing period. Before the study each subject ran two trials with a string attached to his waist. The string was knotted at each 1 yard interval and each knot triggered a pen which marked a paper strip. The paper was driven by a motor at a set speed. The distance between marks gave a good indication of the subject's running speed. (Times from the paper matched stop watch times).

SEGMENT OF THE 100 METRES ANALYZED

Although the total race was filmed, an analysis for stride length and rate was performed from the first foot contact past the starting line (allowing the camera to accelerate to full speed). The total number of strides were calculated to the point where his chest passed the 105 yard (96.3) marker. Stride length was computed as to the last point the runner's foot contacted the track before the 105 yard marker (nearer the starting line).

TRAINING METHODS

The two training methods were highspeed treadmill and track sprinting. One group served as a control. All groups were instructed to continue with their normal activities and training but not to change the type of training.

All groups participated for thirty sessions of training over a six week period. Testing took place prior to and following this six week period. All training was done with five sessions per week.

TREADMILL TRAINING

With an estimate of the subjects maximum running speed from the pretest, a starting treadmill speed was determined. The subject performed seven trial sprints at this speed with three minute rest intervals. The duration of each sprint was 7, 7, 10, 13, 10, 7, 7 seconds (each including 3 seconds for the treadmill to accelerate to the full speed).

Subjects ran at their maximum speed as determined in the pretest for three days. The treadmill speed was then increased by ½ m.p.h. and this new speed was held for three sessions. The speed of the treadmill was increased similarly throughout training sessions if the subject was able to accomodate at the higher speed. If the subject could not keep up with the new treadmill speed, speed was reduced to the previous level until the subject could proceed to the next speed. Inability to keep up with the treadmill was determined by the subject being pulled to the back of the treadmill.

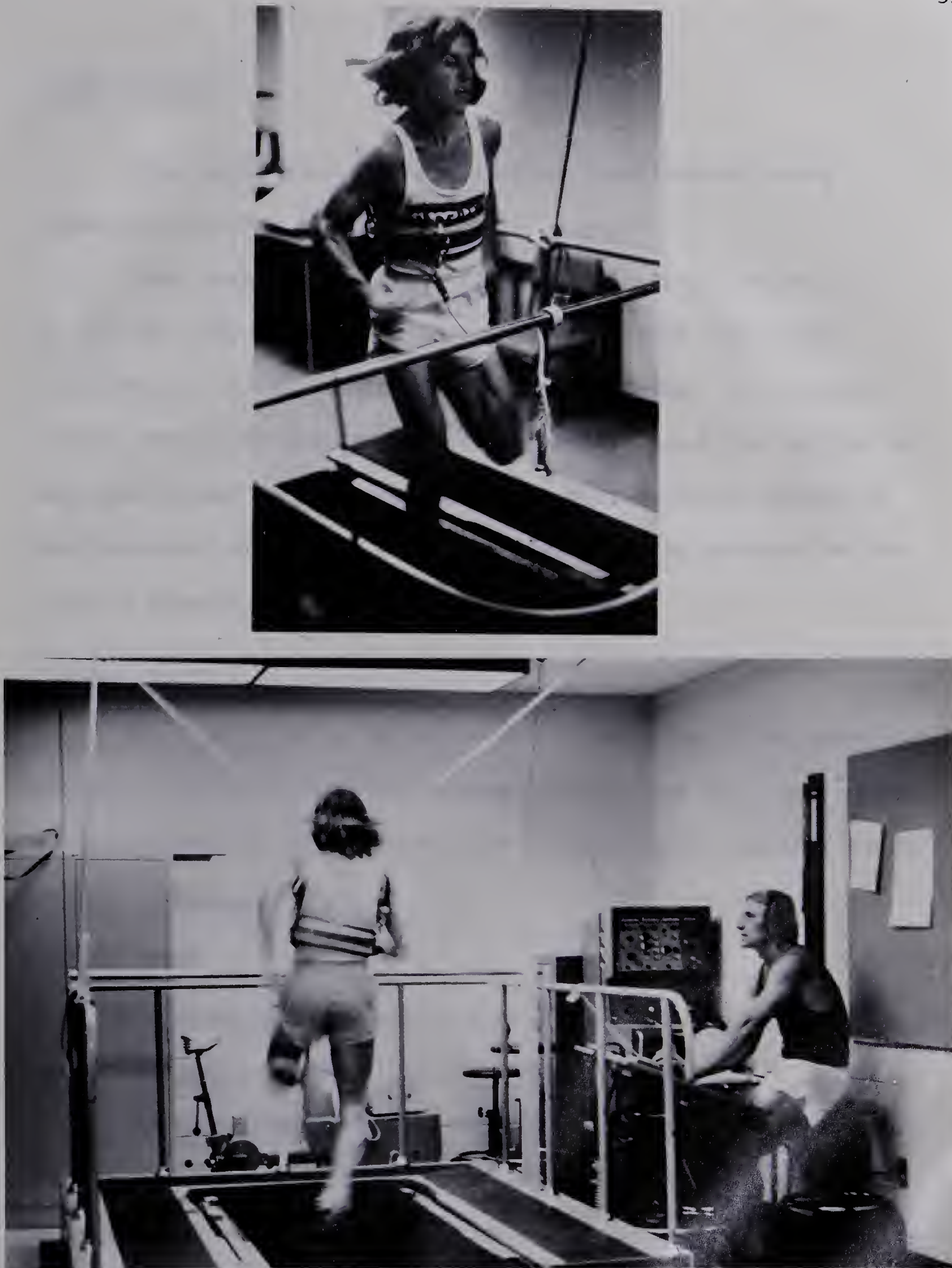


FIGURE IV

SUBJECT TRAINING ON TREADMILL WITH
SAFETY HARNESS, FRONT AND REAR VIEW

SPRINT TRAINING

This group trained on a track or level terrain using conventional sprint training.

Each workout consisted of seven full effort sprints of 60- 60- 80- 100- 80- 60 metres. These distances were chosen to correspond to the treadmill training intervals. The recovery between these full out sprints was the time it took the subject to walk back slowly to the starting line. Most subjects trained on the University of Alberta Track and used the film markings on the track to measure the distance of each sprint.

CONTROL GROUP

The control group performed no set training. They were advised, as were the training groups, to continue with their usual activities but not change their type of training or activity level.

TESTING PROCEDURE

TIME OF STUDY

The study was conducted for an 8 week period (including testing) in July and early August, 1972, in Edmonton, Alberta.

The test runs were all performed on the grasstex composition track at the University of Alberta. All training was done on the University of Alberta treadmill located on the fourth floor of the Physical Education Centre.

Wind speed was checked constantly by observation of a flag south of the track which would indicate aiding or hindering winds.

TEST RUNS

Subjects dressed in running gear and footwear of their choice. The only restriction on footwear was that each subject wear the same footwear in each of his test runs.

START

No subjects were allowed to use starting blocks or assistance of any kind (all runners chose to start from a crouch position). The runs were started by a starter giving three verbal commands accompanied by a signal: " On your mark", "set", "go". For the timers, the starter raised a hand straight in the air when he said "on your marks" and then lowered it on the "go" command. A group of four experienced timers were used throughout the study and were advised to start their watches as soon as the starters hand moved downward.

Watches were stopped when the runner's chest crossed the finish line. When possible, subjects ran together who were approximately equal in running speed. When only one runner was present, a person who was running or training at the track, was asked to run with the subject.

Each subject was allowed adequate time to warm up before being asked to run. He was to jog ½ mile, perform calisthenics, and run some short sprints.

TRACK MARKINGS

The outside lane (furthest from the press box) was measured with a fibreglass tape and marked in 2½ yard intervals. The starting line was marked with 2" masking tape and all other markings were with 1" masking tape. The distances were measured from the edge of the starting line outside the 100m to the edge of the taped zone markers nearest the starting line.

EXPERIMENTAL APPARATUS AND TECHNIQUES

FILMING

A 16 millimeter Bolex movie camera was used for filming and was placed on top of a short tripod. 16 millimeter Kodak TRI-X Reversal (Double Perforated) film in 100 ft. rolls was used. The camera was a spring loaded unit which was fully wound before each run. A battery operated light meter was used before each run to determine light setting for the camera. Filming was done from a press box twenty-five feet above the ground and ninety-five yards from the running surface (Figure V).

The horizontal level of the camera was fixed with a thumb screw and the camera was panned to follow the runners throughout the one hundred metres. The camera, film and procedure was set up with the technical advice of the Motion Picture Division, Technical Services from the University of Alberta. A test roll of 100 ft. was taken before the study to determine the most ideal film speed and light exposure.

FIGURE V

CAMERA SETUP WHILE FILMING A TRACK RUN

FIGURE VI

FILMING HUNTER MODEL 120A KLOCKCOUNTER
TO DETERMINE FILM SPEED

TIMING

An electronic time 'Hunter Klockounter Model 120A was used to measure film speed. As it could not be included on the film, due to the large distance the runners were from the lens, film shots of the timer were taken for two seconds before and after each run (prior to the camera being rewound). Figure VI

It was found that the film reached full speed in less than 10 frames (¼ seconds). Film speed was 41 frames per second ($\pm$ 1) with an average of 41.7 fps.

TABLE II
FILM SPEED

Film Speed Rolls	Speed Setting on Camera	Speed (from film)	Conversion Factor
1 - 4	24 fps	30.0 fps	1.39
5 - 24	32 fps	41.7 fps	1.00

FILM ANALYSIS

STRIDE LENGTH MEASUREMENT TECHNIQUE

All film was viewed through the Recordak Film Analyzer which enlarged the frame size to 8½ x 11". An example of this image is shown in Figure VII.

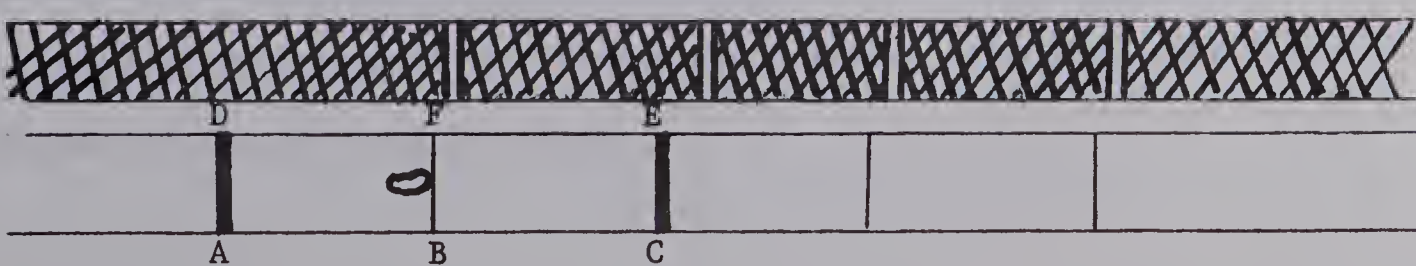


FIGURE VII
FRAME OF FILM AS VIEWED THROUGH RECORDAK FILM ANALYZER

The AC zone in Figure VII is the 2½ yard zone marked on the track and hence appears in each frame. Its size on the film varies as the angle of the lens to the running direction due to the parallex effect. This distance is smallest at the mid point of the run and greatest at either end (start and finish of the run).

All distances are measured from the edges of masking tape nearest the starting line. The ruler is placed on points A and D and a thin ink line AD was drawn on the glass of the Recordak Viewer. A similar line was also drawn over nearer edge of C and E. If the runners foot is closer to AD than CE, then a line parallel to AD is drawn on the most forward edge of the runner's shoe (BF). Where this line intersects the lane marker is called point B. Distances AB and BC are measured along the edge of the lane marker nearest the fence. All distances were recorded in millimetres and measured with a clear plastic ruler (checked against graph paper for accuracy) Figure VIII.

CALCULATIONS

STRIDE LENGTH

Distance AB was divided by distance AC and then this ratio was multiplied by the number of inches in the zone. The AB/AC ratio was multiplied by 90 to determine the distance AB in inches. In order to calculate stride length the distance from the prior foot contact to line AD must be added.

FIGURE VIII

ANALYSIS OF STRIDE LENGTH USING
RECORDAK FILM READER

FIGURE IX

PREVIEWING FILM ON TRIAD V/R 100 FILM VIEWER/READER
TO DETERMINE NUMBER OF FRAMES FOR EACH RUN

EXAMPLE

The subject steps from 60" mark in the previous zone to 40" in present zone. Since we know both zones are 90", we are able to calculate his stride length as (90 - 60) + 40 = 70". All stride lengths were calculated in this manner.

Stride lengths were totalled for six strides and then subjected to statistical analysis. Six strides were chosen as a unit as six represents a small enough portion of the race so stride length and rate changes could be noted in acceleration, maximum speed and deceleration phases. Also subjects stride length from right to left foot was often noted to be greater than the left to right distance, thus it was necessary to use an even number.

STRIDE RATE

This was calculated from viewing the film on the Recordak Film Reader (Figure VIII). The frame in which runners foot first touched the ground was marked with a coloured line. As the frame in the lens could not be marked, a line was placed on the previous frame outside the lens.

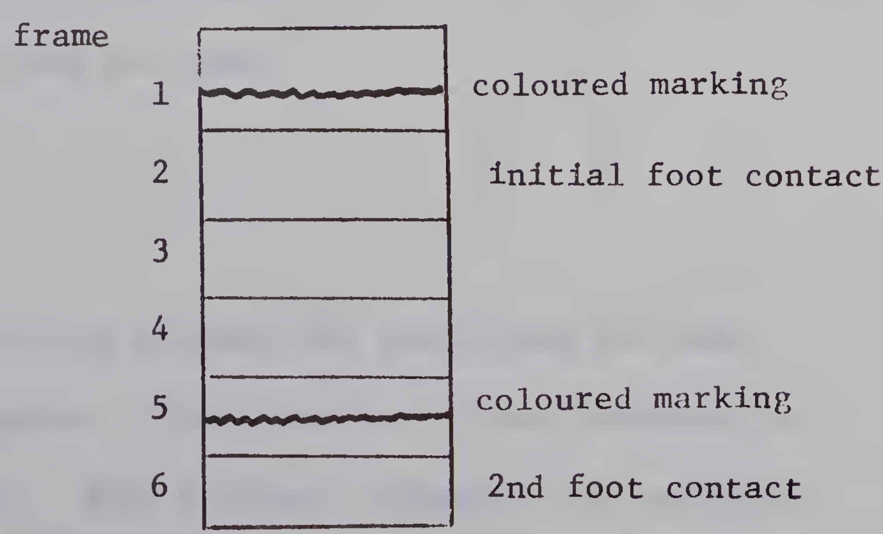


FIGURE X

Markings on Film
Used to Calculate
Stride Rate

The number of frames was counted between the markings from the initial foot contact up to and including the coloured marking preceding the next foot contact.

In the above example, foot contact is first observed in frames 2 and 6. The markings are observed on frames 1 and 5 to determine a stride rate of 4 frames per stride or step. (Stride rates in the study were around 10 fps).

CALIBRATION OF THE APPARATUS

The treadmill speed was calibrated for speed by measuring the length of the belt and then making a tape marking at one point. The treadmill was run at various speeds (as shown on its speedometer) and the number of revolutions were timed at various speedometer settings. The revolutions per minute were multiplied by the length of the belt and this total distance per minute was coverted to miles per hour by simple calculation.

The frame counter on the Triad V/R 100 Film Viewer/Reader was checked by running lengths of film through numerous times and each time reading on the frame counter was the same.

STATISTICAL TREATMENT

STRIDE LENGTH

The distance covered in six strides was calculated for each subject in each testing condition. These distances were compared in a multiple analysis of variance. This statistic measures the variation of each subject's score in the three testing times, compared to his training group, and compared to all subjects in the study. A computer

programme (ANOV 34 (Burnett and Kozlow)) was used to determine significant differences between subjects within a group, between groups and between factors: training methods, segments of the race and testing periods (pre, mid, and post.)

STRIDE RATE

A similar analysis was conducted using the sum of six stride rates (the number of frames for each subject to complete six strides).

CHAPTER 4

RESULTS AND DISCUSSIONS

Analysis of Data

The factors used in the following analysis are: A (training groups including control), B (time of testing (pre, mid, post))and C (stride segments in the 100 metres).

(A) STRIDE LENGTH

(i) Results

TABLE III

SUMMARY OF ANALYSIS OF VARIANCE

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
BET SUBJ	225232.00	20			
A	14176.000	2	7088.000	0.60	0.5570679
SUBJ W GROUP	211056.00	18	11725.332		
WITHIN SUBJ	1708864.0	420			
B	10912.000	2	5456.0000	1.04	0.3622233
AB	10240.000	4	2560.0000	0.49	0.7428864
B X SUBJ W G	188016.00	36	5222.6641		
C	1437616.0	6	239602.62	1763.71	0.0000002
AC	2560.0000	12	213.33333	1.57	0.1110814
C X SUBJ W G	14672.000	108	135.85184		
BC	2656.0000	12	221.33333	1.18	0.2973940
ABC	1744.0000	24	72.666656	0.39	0.9960611
BC X SUBJ W G	40448.000	216	187.25925		

The high F ratio of 1763.71 occurs by chance in 2 of ten million situations with this null hypothesis and hence shows Factor C (the stride length at various positions in the race) is highly significant. The stride length changes significantly throughout the race for all groups and at all testing periods.

TABLE IV

AXB SUMMARY TABLE (TRAINING GROUP X TESTING TIME)

Average Stride Length (Inches)

Training Group	Time of Testing Pre	Mid	Post	Average
Treadmill	451.660	460.335	456.558	456.184
Track	455.525	469.827	470.827	465.393
Control	465.860	461.215	482.372	469.815
(Average)	457.681	463.792	469.919	463.798

None of the changes are statistically significant but the following table points out the changes in training groups over the course of the study that did occur.

TABLE V

CHANGES BY TRAINING GROUP AT VARIOUS TIMES IN THE STUDY (INCHES)

	Pre to Mid	Mid to Post	Pre to Post
	(MEAN)		
Treadmill	(9.7)	(-3.8)	(5.9)
Track	(14.3)	(1.0)	(15.3)
Control	(-6.1)	(21.1)	(15.0)

The track and the control group show overall increases of similar magnitude but the track group's increase was almost exclusively in the first half of the study. The control group had a decrease in stride length in the first half but showed a gain in the last three weeks to account for the increase (over two inches per stride) which was not significant.

The treadmill group gained more than one inch per stride in the first half but lost in the second half to show a net gain of under one inch.

The increase in stride length was less for the treadmill than the track and control groups.

TABLE VI

AXC SUMMARY TABLE (TRAINING GROUPS X STRIDE SEGMENTS)

AVERAGE STRIDE LENGTH (INCHES)								(AVERAGE)
	1-6	7-12	13-18	19-24	25-30	31-36	37-42	
Treadmill	322	423	475	491	497	495	489	456
Track	341	439	481	495	500	503	499	465
Control	340	443	485	502	508	506	505	470
(AVERAGE)	335	435	481	496	502	501	498	464

The AC Factor has a chance occurence probability of only eleven in one hundred and hence is not significant at the p = 0.5 level. However, the nearness of this factor to significance indicates that the training methods produced a different pattern of stride length in the training groups but not enough to be significant.

TABLE VII

CHANGES IN STRIDE LENGTH BY TRAINING GROUP IN SEGMENTS OF THE RACE (INCHES)

	CHANGE FROM SEGMENT					
Group	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7
Treadmill	2115	1099	330	126	-50	-112
Track	2050	895	285	108	53	-85
Control	2171	880	341	127	-32	-33

All groups improve their stride length most from the first six to the second six strides. The length continues to increase between the second and third set of strides but this is only half of the initial increase. Smaller increments are noted until the fifth to sixth set of strides. Here a decrease occured until the end of the race.

The treadmill group has the lowest stride length at each segment of the race although not significantly different from the other training group.

TABLE VIII

BC SUMMARY TABLE (TIME OF TESTING X SEGMENT OF RACE)

AVERAGE STRIDE LENGTH IN INCHES				SEGMENT				
Time of Test	1-6	7-12	13-18	19-24	25-30	31-36	37-42	(Average)
Pre	334	426	473	489	496	494	492	458
Mid	335	439	480	495	500	501	496	464
Post	335	440	489	504	509	508	504	470
(Average)	335	435	481	496	502	501	498	464

The changes that occur in this table have a 25% probability of occuring by chance, which is too high to be significant. There is no change in stride length pattern from the beginning to the end of the study overall in the subjects but average stride length increases as all sections of the race showed increases throughout the study.

TABLE IX

AVERAGE CHANGES IN TIME OF TESTING BY SEGMENT OF THE RACE (INCHES)

	SEGMENTS OF RACE STRIDES							
PART I Times	1-6	7-12	13-18	19-24	25-30	31-36	37-42	(Average)
Pre to Mid	0.5	13.5	7.3	6.7	4.1	6.7	4.0	6.1
Mid to Post	0.0	1.0	9.3	8.4	9.0	7.1	8.1	6.2
Pre to Post	0.5	14.5	16.6	15.1	13.1	13.8	12.1	12.3
PART II	SETS OF STRIDES							
	1 -2	2-3	3-4	4-5	5-6	6-7		
Pre	91.5	47.0	15.9	7.2	-1.5	-2.2		
Mid	104.6	50.8	15.3	4.6	2.1	-4.9		
Post	105.6	49.1	14.4	5.2	-0.8	-3.9		

In Part I it is noted that although the stride length changes for all groups totaled the same for both halves of the study, the pattern was different. Early in the study the greatest, although not significant, changes occured at the beginning of the race. The second half changes appeared more in the middle and later segments of the race.

The pattern of stride length increases (greatest changes occur early) was again evident in Part II. Here it is observed that the

pattern does not change in the pre, mid and post testing conditions.

TABLE X

ABC SUMMARY TABLE (TRAINING GROUP X TESTING TIME X SEGMENT OF RACE)

AVERAGE STRIDE LENGTH IN INCHES

Training Group	Time of Testing	SEGMENT OF RACE STRIDES 1 - 6	7 - 12	13 - 18	19 - 24	25 - 30	31 - 36	37 - 42
Treadmill	Pre	322.443	410.614	465.057	486.400	493.614	493.300	490.200
	Mid	323.600	433.743	482.600	496.928	499.757	497.157	488.571
	Post	321.000	424.914	478.557	490.100	498.014	493.828	489.500
Track	Pre	335.657	426.814	471.014	483.771	491.986	490.728	488.714
	Mid	347.700	445.671	484.585	598.686	501.957	508.043	502.157
	Post	340.114	443.943	488.671	502.543	506.371	509.171	504.986
Control	Pre	344.557	439.885	482.085	495.728	502.085	499.114	497.571
	Mid	332.786	438.371	473.085	490.471	498.186	497.843	497.771
	Post	342.857	452.043	500.857	518.585	522.600	521.385	518.285

The ABC Factors registered an F score of 0.39 which is over 99% able to happen by chance so we can conclude that the training methods did not produce significant changes on the length pattern in the 100 metres at any of the testing times.

TABLE XI

AVERAGE CHANGES IN STRIDE LENGTH IN EACH GROUP, BY TESTING TIMES AND SEGMENT OF THE RACE (INCHES)

		STRIDE SEGMENT						
		1-6	7-12	13-18	19-24	25-30	31-36	37-42
Treadmill	Pre to Mid	1.2	23.1	17.6	10.5	6.1	3.8	-1.7
	Mid to Post	-1.6	-8.8	-4.1	-6.8	-1.7	-3.3	1.0
Track	Pre to Mid	12.1	18.8	13.5	14.9	10.0	17.3	13.4
	Mid to Post	-7.6	-1.7	-4.1	3.9	4.4	1.1	2.8
Control	Pre to Mid	-11.8	-1.5	-9.0	-5.3	-3.9	-1.3	0.2
	Mid to Post	10.1	13.7	27.8	28.1	24.5	23.5	20.5

The treadmill training groups increases in stride length peak in the second to fourth sets of strides in the first half of the study with gains at almost every segment of the race. The decreases are greatest at the same portion of the second half of the race. They total to a lower value than stride length increases to produce an overall stride length increase from the study.

Stride length increases in the track group more than the treadmill group. In the first half of the study there is an increase in stride length in every stride segment of the race. The second half produces a decrease in the first three sets of six strides but increases in the last four sets to balance out the decreases.

The control group's largest but still insignificant decreases occur in the first three sets of strides in the first three weeks of the study. The large increases noted to occur later in the study

are largest from the thirteenth stride to the end of the race.

(ii) Summary and Discussion

Stride lengths found in the present study closely correspond to other research findings: (all numbers are measurements in feet)

	Average Length	Length at 25-40 yards	Maximum Length
Present Study	6.4	6.6	7.1
Deshon & Nelson		6.42	
Hogberg			7.0

This study established that stride length changes significantly as the runner moves down the 100 metres. The largest increases occured in the first twelve strides and continue to increase, although by smaller amounts, until the fifth set of strides. This agrees with Hoffman's findings that maximum stride rate occurs between 50 and 60 metres. A slight decrease is noted in the final two sets of strides.

The experimental groups exhibited differences as to when and how much they gained in stride length. The treadmill group's gains were totally in the first half of the study with smaller decreases in the second half for an overall increase in stride length. The initial increase could be due to the longer stride forced by treadmill turning. The second half decrease may be due to increased stride rate and minimal pushoff jointly working together to reduce stride length. The changes are noted (Table V) and the overall stride rate increase is much less than that reported by Sandwick.

TABLE XII

CHANGES IN STRIDE LENGTH
WITH TREADMILL TRAINING (INCHES)

Weeks	Present Study	Sandwick
1 - 3	9.7	
4 - 6	-3.8	
Overall	0.843 x 7 subjects =5.9"	6" x 7 subjects = 42"

The track training group has a larger increase in stride length than the treadmill but its increases occur also almost totally in the first half of the study. The control group, which totalled the same size increase, initially had a decreased stride length but added 3" to each stride length to increase overall by slightly more than two inches per stride.

The increase in the track training may be the result of increased pushoff from sprint running. The control groups overall increase may have been the result of running the three sets of five sprints which increased their pushoff strength.

(B) STRIDE RATE

(i) Results

TABLE XIII

SUMMARY OF ANALYSIS OF VARIANCE

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Probability
BET SUBJ	1386.0000	20			
A	131.00000	2	65.500000	0.94	0.4091877
SUBJ W GROUP	1255.0000	18	69.722214		
WITHIN SUBJ	3987.0000	420			
B	78.000000	2	39.000000	0.64	0.5344229
AB	139.00000	4	34.750000	0.57	0.6873821
B X SUBJ W G	2202.0000	36	61.166656		
C	566.00000	6	94.333328	35.87	0.0000004
AC	17.000000	12	1.4166660	0.54	0.8849773
C X SUBJ W G	384.00000	108	2.6296291		
BC	46.000000	12	3.8333330	1.37	0.1826410
ABC	50.000000	24	2.0833330	0.74	0.8024033
BC X SUBJ W G	605.00000	216	2.8009253		

Factor A: Training Groups Including Control

B: Time of Testing: Pre (Before), Mid (After 3 weeks), Post (At end of study, 6 weeks).

C: Stride Segment in the 100 metres (6 stride segments)

Factor C showed a significant change in stride rate from different stride segments in the race. The average stride rate (recorded in frames per stride) is recorded in Table XIV.

TABLE XIV

AVERAGE STRIDE RATE (FRAMES PER STRIDE)

	STRIDES						
	1-6	7-12	13-18	19-24	25-30	31-36	37-42
Rate	62.5	59.9	59.4	60.0	60.6	61.4	62.3

It is noted that the fastest rate of stepping occured early in the race in the 13 - 18th stride. A slowing down of rate continued from this point to the end of the run.

TABLE XV

AXB SUMMARY TABLE (TRAINING GROUP X TIME OF TESTING

AVERAGE STRIDE RATE (FRAMES PER STRIDE)				
	Pre	Mid	Post	(Average)
Treadmill	62.488	60.804	61.461	61.584
Track	60.008	60.500	60.251	60.253
Control	60.959	59.633	62.029	60.873
(Average)	61.152	60.312	61.247	60.904

A different pattern of stride rate change was noted for each group although all changes were not significant. The treadmill group decreased their stride rate in the first half of the study but gained part of this amount back in the last three weeks to conclude with a slightly lower stride rate. The track group increased their

rate slightly and then decreased by a lesser amount in the second half to end the study at almost the same rate. The control group decreased in the first half in stride rate but slowed down to a greater extent in the second part to result in a slower stride rate as a result of the six-week study.

TABLE XVI

AXC SUMMARY TABLE (TRAINING GROUP X SEGMENT OF THE RACE)

AVERAGE STRIDE RATE (FRAMES PER STRIDE)

	STRIDE SEGMENT							
Training Group	1-6	7-12	13-18	19-24	25-30	31-36	37-42	(Average)
Treadmill	63.176	60.219	60.171	60.757	61.538	62.219	63.009	61.584
Control	62.543	59.762	59.381	60.190	60.619	61.524	62.095	60.873
(Average)	62.511	59.935	59.421	60.029	60.633	61.435	62.362	60.904

No change in the pattern of stride rate changes is noted between training groups. The highest stride rate (slowest rate of stepping) occured in all groups in the first six strides and the lowest stride rate in the third set of strides (13 - 18 strides).

TABLE XVII

BXC SUMMARY TABLE (TIME OF TESTING X SEGMENT OF RACE)

AVERAGE STRIDE RATE (FRAMES PER STRIDE)

Time of Testing	STRIDE SEGMENT							
	1-6	7-12	13-18	19-24	25-30	31-36	37-42	(Average)
Pre	63.652	60.495	59.452	60.143	60.833	61.271	62.214	61.153
Mid	61.795	59.181	59.024	59.567	59.990	60.876	61.752	60.312
Post	62.086	60.129	59.786	60.376	61.076	62.157	63.119	61.247
(Average)	62.511	59.935	59.421	60.029	60.633	61.435	62.362	60.904
CHANGES								
Pre to Mid		-1.9	-1.3	-0.4	-0.6	-0.9	-0.4	-0.5
Mid to Post		0.3	1.0	0.7	0.8	1.1	1.3	1.4
Pre to Post		-0.3	-0.3	0.2	0.2	0.9	0.9	0.9

In all segments of the race, after the first three weeks, there were decreases in stride rate while the second half of the study resulted in increases. The overall period of training resulted in decreased stride rate in the first two stride segments with increases for the remaining part of the run. All changes are small and non significant.

It was also observed that the overall pattern of stride rate change in the race(decrease until third set of strides and increase thereafter) did not vary in the pre, mid or post testing conditions.

TABLE XVIII

AXBXC SUMMARY TABLE (TRAINING GROUP X TESTING TIME X SEGMENT OF RACE)

AVERAGE STRIDE RATE (FRAMES PER STRIDE)

Training Group	Time of Testing	STRIDE SEGMENT 1 - 6	7 - 12	13-18	19-24	25-30	31-36	37-42
Treadmill	Pre	65.957	60.771	60.614	61.000	62.329	62.886	63.857
	Mid	62.129	59.500	59.686	60.286	60.771	61.157	62.100
	Post	61.443	60.386	60.214	60.986	61.514	62.614	63.071
Track	Pre	61.857	60.429	58.171	58.714	59.457	60.071	61.357
	Mid	62.257	59.329	59.386	59.700	59.914	60.757	62.157
	Post	61.329	59.714	58.571	59.000	59.857	60.857	62.429
Control	Pre	63.143	60.286	59.571	60.714	60.714	60.857	61.429
	Mid	61.000	58.714	58.000	58.714	59.286	60.714	61.000
	Post	63.486	60.286	60.571	61.143	61.857	63.000	63.857

Each training group showed a different pattern of stride rate change throughout the race distance.

The treadmill and control groups decreased their stride rate in the first half of the study. The treadmill group showed increases in the second half of lesser magnitude to show an overall stride rate decrease. However the control group increased by an amount greater than their initial decrease to end up with an overall increase (slower stepping rate).

The track training group showed no pattern to stride rate changes. In the first half of the study they showed increased

stride rate at all segments of the race except one (second set of strides) to record an overall incerase. The second half of the study showed a slight overall decrease with increases in some stride segments. Over the entire study there was no change in rate of stepping.

Also the AXBXC Summary Table's results pointed out the overall stride rate pattern (throughout the race) did not change for any training group or for any time of testing.

(ii) Summary and Discussion

The average maximal stride rates observed in this study were 9.9 frames per stride or 4.2 strides per second (calculated using an average film speed of 41.7 frames per second). This finding concurred with Slater Hammel's leg rate of 3.1 to 4.85 cycles per second found in sprint running.

Using the average maximal stride rate of 6.4 feet, velocity of the runner is calculated to be 25.6 feet per second, which is near Deshon and Nelson's 28.74 feet per second.

The highest stride rate (slowest rate in the first six strides) is to be expected as the subject is just starting to run and is accelerating.

The finding that the fastest stepping occured in the third set of strides or early in the race may show that the runner is not able to maintain the stepping rate. Also it must be noted that stride length is increasing which may account for this decrease. This increased stride rate (slowing down of the stepping rate) occured between 3 and 4.4 seconds or at 21.4 to 35 yards into the race. This pattern

is noted in all groups and at all testing periods in the study. Cavagna however found the lowest stride rate with an international sprinter to be in the early steps when his speed was slowest.

The treadmill group showed the only decrease in stride rate (quickened stepping) but this was not significant. This decrease may be the result of the neuromotor pathway being honed by the treadmill running according to the principles of Clarke and Henry. Dintiman, 1971A cites increased bicycle pedaling ability after training on a motor driven bicycle may also be accounted for by this neuromotor specificity principle. The track and control groups had not experienced the aided or forced faster rate and this may be the reason they did not decrease their stride rate.

(C) NUMBER OF STRIDES TO COMPLETE 100 METER RUN[1]

(i) Results

TABLE XIX

AVERAGE NUMBER OF STRIDES PER 100 METER RUN

TIME OF TESTING			
Training Group	Pre	Mid	Post
Treadmill	46.4	46.3	47
Track	46.3	46.4	45.3
Control	50.0	50.4	50.0

[1]Number of strides are approximations as the runner's last stride did not always fall at the same point on track.

The control group showed no overall change but the number did increase slightly in the first half of the study and fell the same amount in the second half.

The treadmill group decreased ever so slightly early in the study but increased by over half a stride per runner in the second half.

A decreased number of strides in the second half of the study resulted in an overall loss of one stride per run for the track training group.

The treadmill group showed an increased number of strides for the race while the track training group decreased by a full stride per run. Both changes occured in the second half of the study.

(D) SUMMARY OF DISCUSSIONS

Many authors (Doherty, Bennett, Farmer, Hubbard, Jesse and Klafs) cite a strong rearward thrust by the supporting hip, knee, ankle and toe as an essential component of good sprinting. Tsujino has documented this force with the aid of a force sensitive plate that the runners stepped on while sprinting, noting rear and downward components to this force.

Nelson et al compared treadmill and overground running and found that the acceleration (push-off) and deceleration (foot contact and support) phases were not as evident in treadmill running. This

led to the hypothesis that treadmill running does not possess a driving phase and hence stride length should not be stimulated to increase with this type of training.

In the same study it was found that treadmill running had an increased support phase, with the subjects foot contacting the ground further ahead of his centre of gravity than in overground running. With this increase, the period of non-support was shorter, hence the subject was forced to move his legs more quickly to maintain the same running speed. We observe in this study an increased stride rate but not to a significant level.

The increased stride rate may not show to a significant level in the overground testing situation as the training was not related closely enough to the testing situation. If running on the treadmill only involves "picking up one's knees", then when the subject runs on the track, this training is not able to be incorporated into his running style and his stride rate did not change significantly.

However, the stride rate did improve, although not significantly, and if this mode of treadmill training was interspersed with overground sprints the stride rate may improve to a significant degree. In this manner the increased leg movement forced by the treadmill could be incorporated into the running style. Track running would supply the leg muscles with the weight to move in overground running and hence the increased speed could be incorporated into the sprinting action and overall performance would improve.

CHAPTER 5

SUMMARY AND CONCLUSIONS

SUMMARY

The purpose of the study was to investigate the changes in stride length and stride rate in a 100m sprint as a result of two training programmes.

Twenty-one male students attending either the University of Alberta or senior high school in Edmonton volunteered as subjects. They were ranked on time for 100m run and divided into three categories: fastest, next fastest, and slowest. Individuals were picked from each group randomly and two experimental and one control group were created.

Each experimental subject took part in a 30 session training programme with a series of 100m sprints before, halfway through, and at the end of the training period. The control group performed the same tests but did not participate in special training. Two of the 100 metre trials were filmed in each of the three testing periods with a 16mm Bolex camera and high speed TRI-X film. The camera was located in an elevated press box and the subjects ran on a grasstex track 95 yards from the camera. The camera was panned to follow the runners for the full 100 metre distance.

Analysis of variance using a multiple analysis produced two significant scores. These scores showed there was a significant increase in stride length and a significant decrease in stride rate

as the subject performed the 100 metre sprint.

CONCLUSIONS

On the basis of the statistical analysis, the following conclusions are justifiable:

1. The various training methods did not produce any significant difference between groups in stride rate or stride length.
2. Stride length changed significantly as the subjects ran the 100m. Stride length increased by the largest amount early in the race (6 - 12 strides) and did not cease to increase until the 31 - 36 strides.
3. Stride rate changed significantly as the subjects ran the 100 metres. The rate of stepping was the slowest in the first six strides. Stride rate increased in the second set of steps and reached its highest value in the third set (12 - 18) of strides. The striding rate slowed down throughout the race after this point.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. The treadmill training be supplemented by exercises which develop a driving action by the supporting leg (i.e. weight training, or resistive running). Research has shown that increased strength leads to increased stride length and the training would supplement the limited driving forces found in treadmill training.

2. Treadmill training be interspersed with sprinting. Sprinting will enable the stepping rate increases from treadmill training to be incorporated with body weight so the muscles of the leg will be forced to attempt to move the leg at the increased stepping rate. In this manner a more positive transfer of the increased rate of stepping may be attained.
3. Fixed cameras be used in a sequence perpendicular to the runner so that biomechanical data may be collected more economically. The Triad V/R 100 Film Viewer can be used to obtain X-Y coordinates of any body segment so that stride length, rate and centre of gravities may be computed directly.
4. Research be carried out to investigate the differences in treadmill and overground running which include electromyographic and force studies. These apparatas would point out the muscle used and their relative importance so weight training could be more specific.
5. Studies be limited to "good" sprinters as the large variations between subjects stride rate and length are possibly due to intersubject variation. Using all sprinters would reduce this variation and allow closer analysis of training methods.

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APPENDIX A

TOTAL STRIDE LENGTH FOR SIX STRIDE SEGMENTS

NOTE: ALL STRIDE LENGTH TOTALS TO BE READ AS POSSESSING DECIMAL BETWEEN SECOND LAST AND LAST DIGIT (EXAMPLE 3028 is 302.8)

CHART TO MATCH SUBJECT NUMBER TO NAME

GROUP	SUBJECT NUMBER FOR STRIDE LENGTH SCORES	NAME	SUBJECT NUMBER FOR STRIDE RATE SCORES
Treadmill	1	E. Anderson	7
	2	R. Burrows	1
	3	G. Cuff	2
	4	D. Irwin	3
	5	D. Lockhart	4
	6	T. Overend	5
	7	R. Sherbaniuk	6
Track	1	J. Baxter	1
	2	L. Brinker	2
	3	B. Buss	3
	4	R. Cote	4
	5	F. Gutoski	5
	6	L. Stelck	6
	7	G. Stothart	7
Control	1	E. Bennington	1
	2	G. Bailey	2
	3	C. Bonifacio	3
	4	R. Marshall	4
	5	W. McBlain	5
	6	G. Osborne	6
	7	D. Yawrenko	7

PART 1

TREADMILL TRAINING GROUP

STRIDE SEGMENT

Testing Time	Subject	1-6	7-12	13-18	19-24	25-30	31-36	37-42
PRE	1	3028	4064	4448	4485	4601	4583	4518
	2	3410	4517	4854	5009	5091	5082	5023
	3	2916	3914	4696	4699	4700	4718	4663
	4	3239	4348	4821	5024	5101	5271	5077
	5	3392	4402	4961	5024	5069	5203	4963
	6	3437	4552	5079	5237	5395	5364	5452
	7	2772	3672	4871	5345	5521	5552	5624
MID	1	3083	4249	4634	4874	4910	4844	4745
	2	3532	4678	5130	5194	5271	5284	5237
	3	3408	4032	4360	4568	4578	4578	4462
	4	3319	4405	5067	5247	5308	5299	5173
	5	3581	4864	5522	5625	5771	5725	5563
	6	3741	4529	4926	5024	5071	5146	5099
	7	3092	4393	4843	4967	5067	4931	4949
POST	1	3060	3914	4356	4521	4591	4463	4509
	2	2777	3543	4060	4316	4508	4234	4291
	3	3303	4482	4954	5154	5056	5023	5043
	4	2858	3840	4286	4406	4344	4374	4263
	5	3606	4555	5068	5286	5173	5167	5243
	6	3053	3914	4469	4510	4482	4419	4304
	7	3086	3982	4430	4625	4789	4640	4578

TRACK TRAINING GROUP

STRIDE SEGMENT

sting Time	Subject	1-6	7-12	13-18	19-24	25-30	31-36	37-42
RE	1	3155	3971	4340	4441	4531	4619	4459
	2	3453	4278	4684	4946	4935	5035	4973
	3	3018	4205	4693	4757	4836	4992	4835
	4	3394	4415	4911	5004	5056	5049	5169
	5	3441	4558	4933	5044	5069	5222	5256
	6	3446	4626	5069	5214	5218	5210	5299
	7	3792	5058	5389	5512	5572	5562	5718
ID	1	3517	4428	4996	5157	5159	5187	5044
	2	3860	5009	5420	5722	5739	5822	5976
	3	3132	4068	4595	4681	4704	4673	4534
	4	3619	4716	5060	5146	5164	5218	5145
	5	3572	4406	4776	4919	4984	5036	4885
	6	3181	4027	4535	4780	4899	4850	4753
	7	3480	4442	4897	5068	5108	5131	5056
OST	1	3508	4332	4685	4731	4745	4736	4591
	2	3321	3795	4290	4435	4627	4507	4620
	3	3332	4393	4795	4939	5045	4031	5037
	4	3331	4441	5014	5162	5199	5195	5106
	5	3521	4543	4911	5011	5050	5091	4957
	6	3497	4382	4556	4608	4657	4739	4640
	7	3073	4057	4550	4673	4725	4651	4657

CONTROL GROUP

STRIDE SEGMENT

Testing Time	Subject	1-6	7-12	13-18	19-24	25-30	31-36	37-42
PRE	1	3212	4136	4519	4684	4691	4710	4636
	2	3420	4348	4700	4857	4897	4928	4939
	3	3218	4226	4853	4821	4921	5010	5025
	4	3586	4627	4917	5004	5212	5151	5114
	5	3460	4289	4662	4883	4992	5033	4967
	6	3379	4542	5015	5208	5222	5146	5133
	7	3894	4966	5319	5569	5578	5594	5659
MID	1	3379	4755	5192	5193	5234	5119	5176
	2	3908	5004	5548	5860	5866	5904	5924
	3	3508	4247	4843	4843	4859	4760	4815
	4	3577	4758	5082	5136	5266	5268	5241
	5	3523	4847	5415	5617	5683	5618	5515
	6	3601	4548	4912	4961	4984	4969	4974
	7	3013	4103	4676	4964	5097	5203	5249
POST	1	3513	4460	4732	4955	4920	4833	4839
	2	3094	4054	4389	4517	4681	4593	4538
	3	3104	4274	4569	4841	4950	4835	4891
	4	3447	4627	5166	5269	5366	5246	5221
	5	3224	4214	4847	5123	5141	5161	5094
	6	3342	4159	4235	4459	4437	4463	4381
	7	3012	3937	4331	4571	4604	4740	4623

APPENDIX B

TOTAL STRIDE RATE FOR SIX STRIDE SEGMENT

NOTE: ALL STRIDE RATE TOTALS TO BE READ AS POSSESSING DECIMAL BETWEEN SECOND LAST AND LAST DIGIT
(EXAMPLE 658 is 65.8)

TREADMILL

STRIDE SEGMENT

sting Time	Subject	1-6	7-12	13-18	19-24	25-30	31-36	37-42
RE	1	658	589	603	575	603	603	603
	2	589	603	603	617	617	617	630
	3	646	630	630	640	640	660	660
	4	650	600	610	610	620	640	660
	5	726	617	630	644	644	685	698
	6	630	640	630	650	650	650	650
	7	610	610	610	610	600	610	620
ID	1	610	610	610	600	610	610	610
	2	617	644	644	644	644	658	658
	3	685	617	603	658	658	644	658
	4	644	575	575	589	603	589	589
	5	671	630	658	658	671	685	699
	6	699	658	630	617	658	671	671
	7	550	590	580	570	570	590	580
)ST	1	534	534	521	548	562	575	603
	2	630	550	570	570	580	590	600
	3	620	610	620	640	650	630	660
	4	603	589	562	559	559	575	555
	5	685	630	617	630	644	644	658
	6	610	560	560	560	560	560	580
	7	600	560	570	570	580	580	590

TRACK

esting Time	Subject	STRIDE SEGMENT 1-6	7-12	13-18	19-24	25-30	31-36	37-42
PRE	1	600	550	550	560	550	570	580
	2	600	580	590	580	580	600	620
	3	600	600	610	610	620	620	640
	4	610	690	570	590	590	620	640
	5	610	600	620	620	620	624	655
	6	640	620	600	610	610	610	650
	7	620	610	570	560	580	580	590
IID	1	640	610	620	630	640	640	650
	2	650	620	630	640	640	660	690
	3	634	610	620	620	630	630	630
	4	610	590	580	570	570	560	570
	5	603	580	590	580	590	590	610
	6	572	550	540	550	552	555	555
	7	618	593	597	599	604	609	616
OST	1	580	530	530	540	580	600	620
	2	640	620	610	620	640	630	640
	3	650	610	580	610	600	610	630
	4	630	590	600	610	610	630	630
	5	654	600	612	610	620	620	660
	6	630	570	570	570	580	610	610
	7	590	640	540	540	540	550	530

CONTROL
STRIDE SEGMENT

'esting Time	Subject	1-6	7-12	13-18	19-24	25-30	31-36	37-42
PRE	1	630	590	590	580	580	590	590
	2	630	610	590	610	600	630	620
	3	634	610	590	600	610	610	620
	4	610	580	550	590	590	590	600
	5	620	590	610	600	610	610	610
	6	670	650	630	640	630	630	640
	7	600	600	590	600	600	590	610
MID	1	630	630	620	640	650	670	660
	2	640	610	620	640	640	650	670
	3	650	640	650	650	660	660	660
	4	600	590	570	560	570	580	580
	5	650	620	640	660	670	690	680
	6	660	610	580	590	580	590	600
	7	560	560	560	560	560	580	590
POST	1	630	600	590	570	580	610	620
	2	630	620	600	630	620	630	620
	3	610	560	560	570	590	590	610
	4	610	610	630	620	640	650	650
	5	640	580	610	610	620	610	620
	6	620	570	550	570	570	590	600
	7	610	520	540	550	560	570	590

APPENDIX C

TOTAL NUMBER OF STRIDES IN SUBJECTS FASTEST RUN

GROUP/SUBJECTS	TIME OF TESTING		
Treadmill	Pre	Mid	Post
Anderson	51	52	52
Burrows	44	48	48
Cuff	50	49	48
Irwin	45	46	43
Lockhart	47	45	48
Overend	44	42	46
Sherbaniuk	44	42	42
Track			
Baxter	47	46	46
Brinker	43	43	41
Buss	51	52	48
Cole	47	46	45
Gutoski	43	43	43
Stelck	45	48	47
Stothart	48	47	47
Control			
Bennington	52	49	48
Bailey	55	51	51
Bonifacio	46	48	49
Marshall	51	47	48
McBlain	45	50	48
Osborne	48	53	54
Yawrenko	52	54	52

APPENDIX D

TOTAL NUMBER OF FRAMES FOR ALL FILMED RUNS

SUBJECTS	TIME OF FILMING		
	PRE	MID	POST
Gutoski	491	545 518 520	503 513 478*
Baxter	520	536 533	529 520
Cuff	569 533	518 519	522 434* 526 561
Sherbaniuk	507	484 465	463* 479 466 495
Stelck	512	505 505	498 520
McBlain	519	525 523	532 535
Buss	592	561 270*	557 588 586
Irwin	535	523 526	499 434* 523 492 520 399*
Bennington	542	534* 551 564	534 531
Cote	480 495*	471 464	460 474 463 489
Anderson	541	535 535	560 533 531 533
Burrows	499 522	473 446*	527 492 508 501 502
Lockhart	522	493	524 500 497
G Stothart	489 503	269* 273*	492 528 488 486 481
Bonifacio	522 546	505 490	506 526
Bailey	589 560	536 542	545 553
Osborne	534	540 560 528	560 543 542
Yawrenko	522 530	502 513	546 495
Overend	503	496* 510	533 539 593 505 503 552 529
Brinker	474 480	471	461 478 495
Marshall	514 521 523	513 502	515 518 510 523

* All of run not filmed, partial frame count